Computer-Based Short-Term Hydrothermal Generation Scheduling

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Abstract

This paper presents a solution of a short term hydrothermal scheduling using Computer Approach and software MATLAB. The technique is used to handle the problems of short-term hydrothermal scheduling and economic load dispatch while satisfying and thermal constraints in order to minimize the total system cost. This technique is tested on a system consisting of a hydro plant and a thermal plant and the outputs are obtained by using the λ-γ iteration.

Index terms – Hydrothermal scheduling, Computer Approach, Power Generation, Hydrothermal Unit Commitment, Matlab Programming

1. INTRODUCTION

Nowadays in power systems, the efficient scheduling of available energy sources for satisfying load demand has become an important task. The short term hydrothermal scheduling is one day to one week involves the hour by hour scheduling of all generation on a certain system. The generating scheduling problems consists of determining the optimal operation, subject to variety of constraint [5].

The objective of this project is to develop a computer based optimal operation of scheduling thermal units and hydro plants that minimizes total thermal production cost while considering various local and coupling constraints in order to meet the forecasted demand. Since the operation of a power system is characterized by having to maintain a high degree of economical and reliability [2], the hydrothermal scheduling plays an important role in power system operation planning. Hydrothermal scheduling is mainly concerned with hydro units scheduling and thermal units dispatching, and is more complex than the scheduling of an all-thermal generation system [1].

It is dominantly thermal unit power system, hydro units are usually scheduled for peak load periods as they are less expensive and can be started up and shut down more efficiently. The scheduling of hydrothermal units in power system is one of the most important problems to be solved when hydroelectric plants are a part of the system. The solution will allow the operators to distribute the hydroelectric generation in each reservoir system and to allocate the generation to the committed thermal units so that the fuel expenditure during the period is minimized while satisfying a series of constraints [3]. At the end of this paper, it can be show that the programming for the short term hydro thermal scheduling had achieved the minimum production cost for the given time period and load demand.

2. λ -γ ITERATION

In this project there are can be many method of solving the short term scheduling generation problem such as Simulated Annealing (SA), Genetic, Algorithm (GA), Evolutionary Strategy (ES), and Evolutionary Programming (EP). Here is the step for the approach to solving the short term hydrothermal scheduling problem:

1. The incremental water rate for hydro plant, incremental fuel cost for the thermal plants, desired water for the hydro plant over the optimization period, estimated hourly load demand are read in.
2. An initial guess is made for γ_h.
3. The hour count is started.
4. For each hour, a value of λ^0 is selected so that no generation is negative (λ^0 is the incremental production cost). Selection of λ^0 depends on the load demand to be satisfied.
5. The generations are calculated by the solving the following equation:
   $$\frac{dFi(Pth)}{d(Pth)} = \lambda^0, i = 1,2,\dots,\alpha \qquad (2.1)$$
   and
   $$\gamma_h \frac{dW(Ph)}{d(Ph)} = \lambda^0, i = \alpha + 1, 2 + \alpha, \dots, \beta (2.2)$$
6. A check is made to observe whether the generations satisfy the load demand or not. If the demand is not met, λ^0 is to be modified through the iterative process as detailed earlier and again the generation demand equality is checked. The iterative procedure is continued until the demand is satisfied.

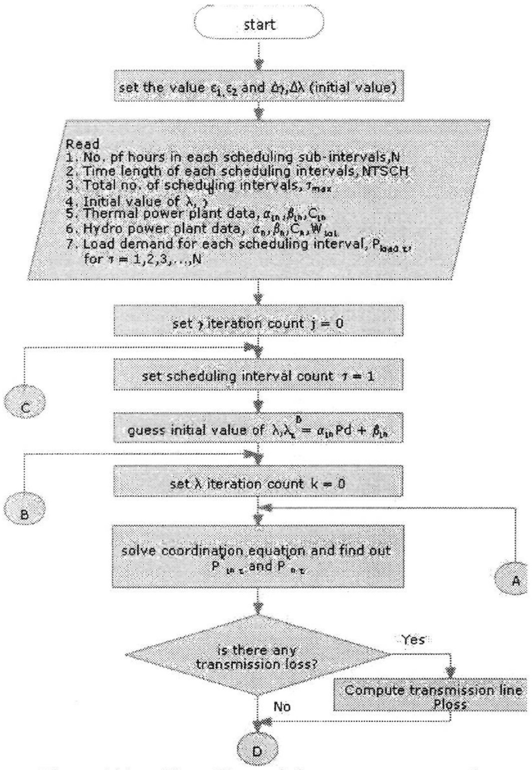

Figure 1(a) – Flow Chart of the computer approach programming

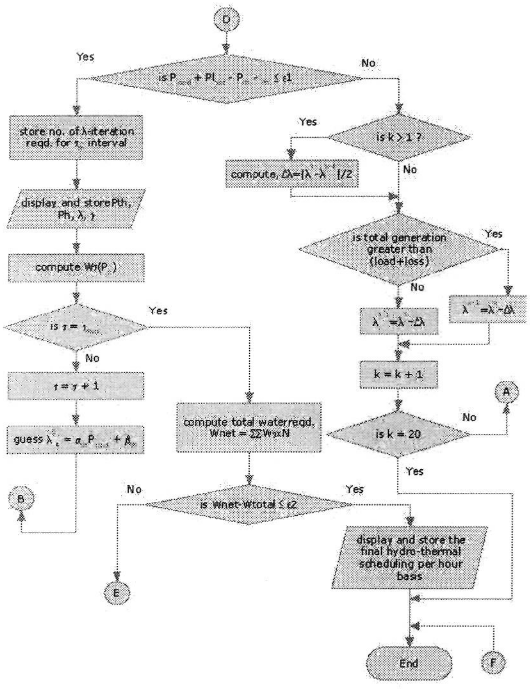

Figure 1(b) – Flow Chart of the computer approach programming(cont.)

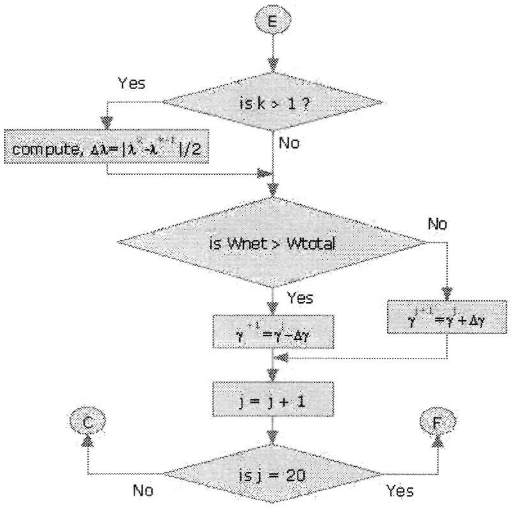

Figure 1(c) – Flow Chart of the computer approach programming(cont.)

7. The procedure is repeated 24hours by increment of the hour count by 1.
8. The water withdrawal from each hydro plant is calculated over the specified scheduling period.
9. If the different between the calculated water withdrawal and scheduled water withdrawal is not within a prescribed tolerance, then γ_h is adjusted and the procedure is repeated until this criterion is satisfied.
10. When the criterion in step 9 is satisfied, the sub-optional results have been achieved.

3. PROBLEM FORMULATION

When a specified load is to be supplied by a number of steam and hydro generation resources, the total cost of operation depends upon the load allocation to the various resources. If the load can be supplied by the resources, there exists a particular schedule of allocation that will result in minimum cost of generation [6].

In this case, for the sake of simplicity, the power system has been assumed to be composed of a thermal plant and a hydro plant supporting total load P_{load}. Assuming that the hydro plant alone is not sufficient to supply the load demand during the period and that there is a maximum total volume of water outflow throughout the period of T_{max} hour [4], the problem can be formulated by stating:

$$\text{Min } F_c = \sum_{\tau=1}^{\tau max} n_\tau F_\tau \tag{3.1}$$

Assuming the constraint with no spillage, the total water discharge is given by

$$W_{total} = \sum_{\tau=1}^{\tau max} n_\tau W_\tau \qquad (3.2)$$

Where, τ = interval of short term operation,

$W_{\tau i}$ = inflow during τ interval,

v_τ = volume of water flow at the end of τ period,

$W_{\tau 0}$ = water discharge during τ period,

S_j = spillage of water,

n_τ = length of time in τ-th interval,

F_c = total cost function

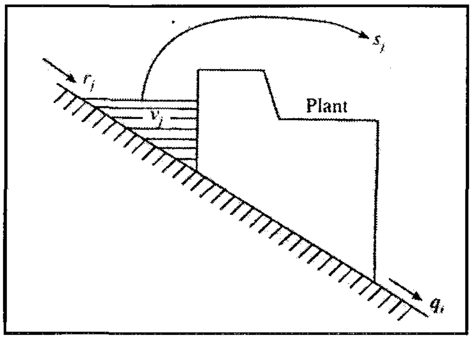

Figure 2 – Scheduling parameter for Hydro plant

Again, for total load balance,

$$P_{load\,\tau} = P_{h\,\tau} + P_{th\,\tau} \qquad \mathbf{(3.3)}$$

Where, $P_{load\,\tau}$ = total load during τ time

$P_{h\,\tau}$ = hydro output during τ time

and $P_{th\,\tau}$ = thermal output during τ time.

But , $\sum_{\tau=1}^{\tau max} T_{max}$

It has further been assumed that:

- Load is remaining constant during the assumed period of scheduling.
- Starting water volume is $v_s(v_s = v_\tau$ at $\tau = 0)$.
- Ending volume is v_e (i.e. $v_e = v_\tau$ at $\tau = \tau_{max}$).
- Flow limits are maintained such that $W_{min} < W_\tau < W_{max}$.
- Discharge remains fixed for the particular interval τ.
- Discharge is a function of hydro power generation.
- There is no spillage ($S_j = 0$).

The generalized cost function characteristics for thermal plant being given by

$$F(P_{th}) = \alpha_{th} P_{th}^2 + \beta_{th} P_{th} + \gamma_{th} \qquad (3.4)$$

It can be write as

$$\frac{dF(P_{th})}{dP_{th}} = 2\alpha_{th} P_{th}^2 + \beta_{th} \qquad (3.5)$$

For short term hydro-thermal schedule, the coordination equation for the thermal plant with transmission loss not considered is given by equation

$$\lambda = n_\tau \frac{dF(P_{th})}{dP_{th}}$$

$$\lambda = n_\tau [2\alpha_{th} P_{th} + \beta_{th}] \qquad (3.6)$$

$$P_{th} = \frac{\lambda - \beta_{th} n_\tau}{2\alpha_{th} P_{th}} \qquad (3.7)$$

However, the transmission loss (P_l) being considered,

$$F(P_{th}) = \alpha_{th} P_{th}^2 + \beta_{th} P_{th} + \gamma_{th}$$

$$\text{and } P_l = C_{th} P_{th}^2 \qquad (3.8)$$

Where C_{th} represents the coefficient.,

$$\frac{dF(P_{th})}{dP_{th}} = 2\alpha_{th} P_{th}^2 + \beta_{th} \qquad (3.9)$$

$$\text{and} \frac{dP_l(P_{th})}{d(P_{th})} = 2C_{th} P_{th} \qquad (3.10)$$

The optimal operation for thermal plant can be write as

$$n_\tau(\beta_{th} + 2\alpha_{th} P_{th}) + \lambda_\tau(2C_{th} P_{th}) = \lambda_\tau$$

$$P_{th}(2\alpha_{th} n_\tau + 2\lambda_\tau C_{th}) = \lambda_\tau - n_\tau \beta_{th}$$

$$P_{th} = \frac{\lambda_\tau - n_\tau \beta_{th}}{2\alpha_{th} n_\tau + 2\lambda_\tau C_{th}} \qquad (3.11)$$

For hydro plant and loss characteristics being given by

$$F(P_h) = \alpha_h P_h + \beta_h \text{ and } P_l = C_h P_h^2$$

The optimal operation for hydro plant can be write as

$$n_\tau \gamma \alpha_h + \lambda_\tau (2C_h P_h) = \lambda_\tau$$

$$P_h = \frac{\lambda_\tau - \gamma n_\tau \alpha_h}{2\lambda_\tau C_h} \text{.........} (3.12)$$

For the power tolerance,dP = Pload – Pgeneration

and it must fulfill the condition of $|dP| > \varepsilon_1$

For the tolerance in water required and water available, dW = $W_{net} - W_{total}$

and it must fulfill the condition of $|dW| > \varepsilon_2$

4. NUMERICAL RESULT

The program of the λ – γ iteration are to solve the short term hydrothermal scheduling problem has been successfully run and get the desired requirement by using the MATLAB programming. The program is assumed to give an output that met the condition mention earlier. The program had run 3 types of load with difference interval of scheduling. The outputs of the programming are shown in table below.

Table 4.1 : The output of the programming for one load demand.

$P_{load}(MW)$	800
T_{max}(hours)	12
λ – iteration,k	16
γ – iteration,j	19
$P_{loss}(MW)$	0.823
$P_{th}(MW)$	373.0302
$P_h(MW)$	427.7778
λ	9.492121
γ	1.575929E-3

Table 4.2 : The output of the programming for two load demand.

$P_{load}(MW)$	740	900
T_{max}(hours)	12	12
λ – iteration,k	11	17
γ – iteration,j	19	19
$P_{loss}(MW)$	0.465	1.031
$P_{th}(MW)$	419.0724	422.5075
$P_h(MW)$	321.4498	478.5504
λ	9.676274	9.69003
γ	1.608049E-3	1.608049E-3

Table 4.3 : The output of the programming for four load demand.

P_{load} (MW)	740	900	830	640
T_{max} (hours)	6	6	6	6
λ– iteration,k	16	16	17	17
γ– iteration,j	19	19	19	19
P_{loss} (MW)	0.506	1.092	0.808	0.253
P_{th} (MW)	405.1335	408.5495	407.0539	403.0039
P_h (MW)	335.395	492.5044	423.7726	237.2205
λ	9.6204	9.6341	9.6282	9.6120
γ	1.589e-3	1.598e-3	1.598e-3	1.598e-3

5. CONCLUSION

As the conclusion, in this paper the λ – γ iteration programming successfully run to solving the short term hydrothermal scheduling problem. The programming developed in this paper is capable to design the suitable schedule for hydrothermal plant, which can minimize the cost of the generation for that plant. The programming can solve the different types of intervals. The results also show that the system manages is able to deliver the power at the specified load demand.

6. FUTURE DEVELOPMENT

For the future development in power system generation, it is necessary use another method in Artificial Intelligence hierarchy such as GA and ES and combines with the λ-γ iteration to obtain the more accurate output. Other than that, there are also can make an analysis with same load demand and different input of parameter to improve the usage of the program has been developed for generation in power system.

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